Atomic Theory

It is our intention here to handle atomic theory in a very light manner. Some knowledge is required in order to understand the characteristics of semi-conductors. Your textbook, in Chapter 2, will give you a more in-depth explanation.

The Atom

Figure 1 shows a representation of the Bohr atom. The atom contains three basic particles; ***protons*** and ***neutrons*** that make up the ***nucleus*** of the atom and ***electrons*** that orbit the nucleus.

- The ***protons*** have a ***one positive charge*** and have ***weight***
- The ***neutrons*** have ***no charge*** and have ***weight***
- The ***electrons*** have ***one negative charge*** and have ***negligible weight***

- Protons & neutrons collect in the nucleus.

- The electrons orbit the nucleus.

- The number of ***electrons*** orbiting the atom ***must equal*** the number of ***protons*** in the nucleus if the atom is ***neutral.***

- Electrons travel in paths or shells. They normally stay in their shell unless they are affected by some outside force

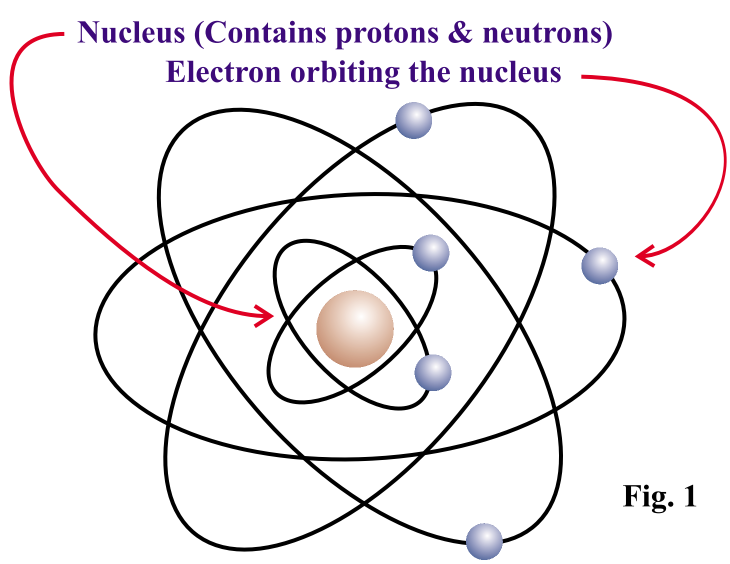
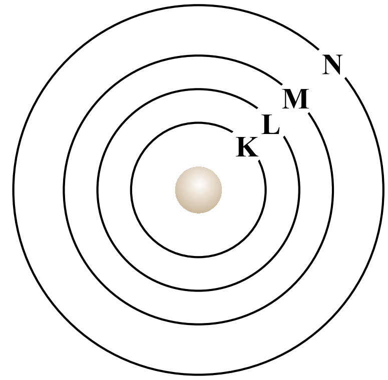


Fig. 1

The Bohr Model

The orbital paths or shells are identified using letters K through Q. The inner most shell is the K shell, followed by the L shell. The other shells are labelled as shown in Figure 2. The outer most shell for a given atom is called the valence shell. The valence shell is important because it determines the conductivity of the atom.



Shells or Energy Levels

Figure 2

The valence shell of atom can contain up to eight electrons. The conductivity of the atom depends on the number of electrons that are in the valence shell. When an atom has only one electron in valence shell, it is almost a perfect conductor. When an atom has eight valence electrons the valence shell is said to be complete and the atom is an insulator. Therefore ***conductivity decreases with an increase in the number of valence electrons***.

Conductors

A conductor is a material that allows electrons to easily pass through it. Copper is a good conductor. Note that the valence shell has only one electron.

With atoms:

- K is full with 2 electrons
- L is full with 8 electrons
- M is full with 18 electrons

This totals 28 electrons with 1 electron left in the N shell (valence shell for copper)

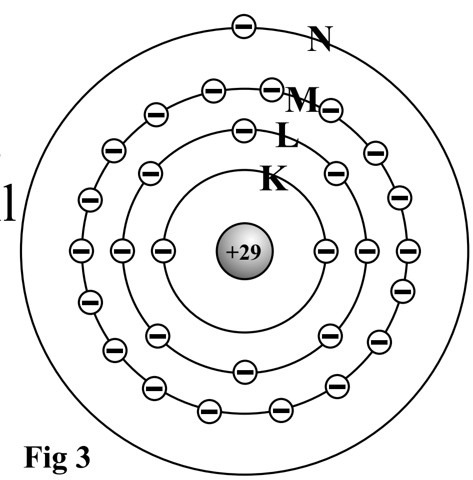


Fig 3

Copper Atom
29 protons
29 electrons
35 neutrons

The valence shell ideally needs 8 electrons to be full but copper has only one. The energy required to allow this electron to escape the valence shell and become free depends on the number of electrons in the valence shell. Since there is only one here, freedom is easy. A slight voltage force will free it. Even the heat at room temperature will free some of them.

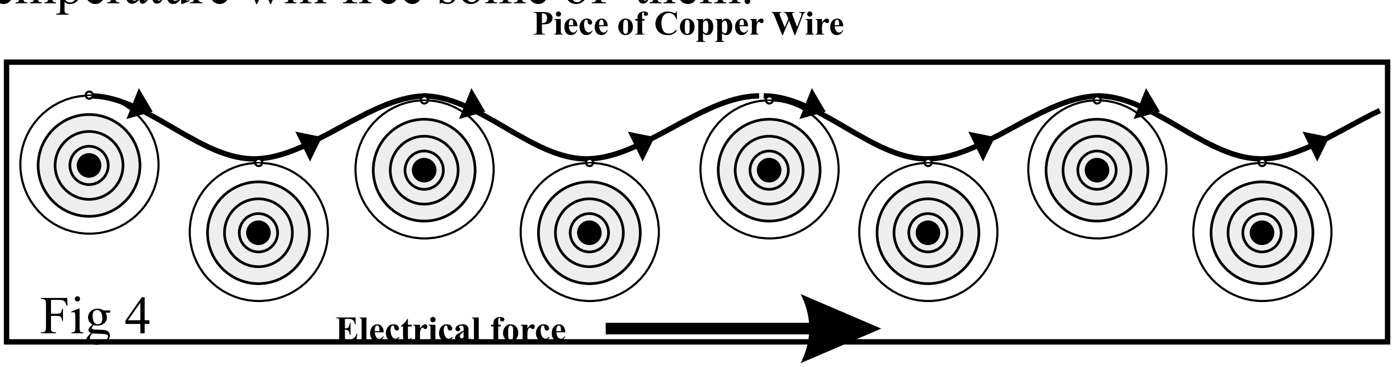


Fig 4

Application of a the slightest electrical force will cause these electrons to move from atom to atom down the wire.

The best conductors are Silver , Copper & Gold. ***All have one valence electron.***

Insulators

Materials that do not conduct are termed insulators.(I.E. glass, porcelain, plastic, rubber. The covering on electrical wire is an insulator.
Insulators do not conduct because they have a full or nearly full valence shell and thus their electrons are tightly bound.

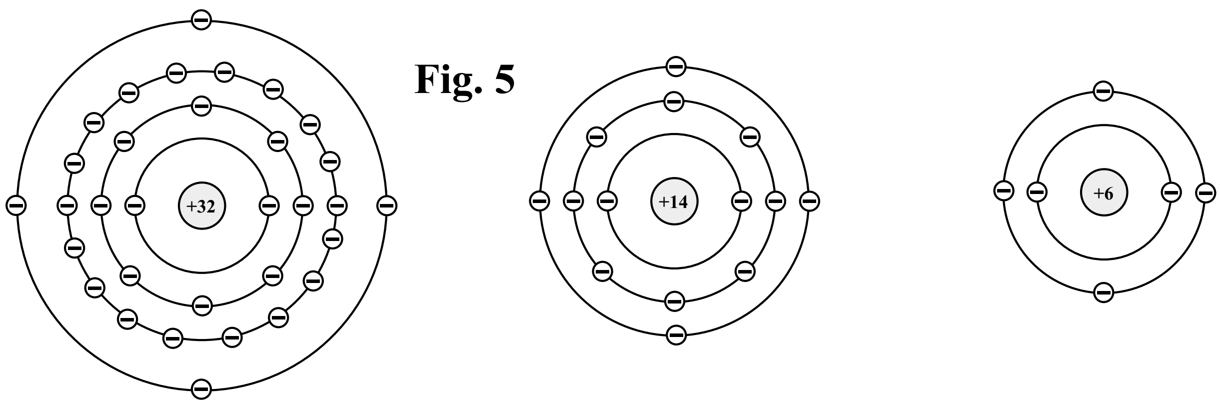
If a high enough voltage is applied to an insulator, the force is so great that the electrons are literally torn from their parent atoms.

This will cause conduction to occur. In air you will see this as an arc or flash over. In solid materials the heat generated will char the material.

Semiconductors

Three of the most commonly used semiconductor materials are silicon (Si), germanium (Ge), and carbon (C). These atoms are shown Figure 5.. Note that all of them have 4 valence electrons.

Fig. 5



Germanium Atom Silicon Atom Carbon Atom

Remember that a good conductor has 1 valence electrons and an insulator has eight valence electrons.

The semiconductor has 4 valence electrons. It is neither a good conductor or a good insulator.

Semi-conductors have some unique properties that we will discuss later

Conductors, Insulators, and Semi-Conductors

Electrically, all materials fall into one of the three classifications
Conductor --- Semi- Conductor --- Insulator

Ions

When the number of protons in an atom equals the number of electrons the atom is said to be neutral. When no outside force causes conduction, the atom will remain neutral.

If an atom loses one valence electron, then the net charge on the atom is positive. The atom is now have positive ion.

If an atom with an incomplete valence shell gains one valence electron, then the atom would be negative. This is because there would be one extra electron in the atom.

In summary, if the atom has more electrons then protons, it will have a negative charge and become a negative ion. If the atom has more protons that electrons it will have a positive charge and become a positive ion.

Coulomb's Law

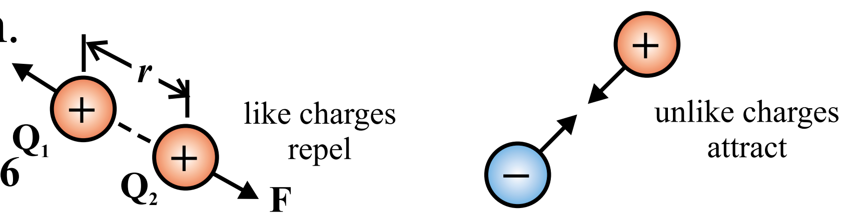


Fig. 6

You probably learned Coulomb's law in physics. He determined that the force between two charges Q_1 and Q_2 is directly proportional to the product of their charges and inversely proportional to the square of the distance between them.(See Fig. 6) Mathematically, Coulomb's law states:

$$F = k\frac{Q_1 Q_2}{r^2} \quad \text{[newtons N]}$$

where: Q_1,Q_2 are the charges in Coulombs
r is the centre to centre spacing between them in meters
k is the constant of 9×10^9

See example 21 Page 35 R & M

The unit of electrical charge: The Coulomb

The unit of electrical charge is the Coulomb (C).The Coulomb is defined as the charge carried by $6.24x10^{18}$ electrons.
If an electrically neutral body has $6.24x10^{18}$ electrons removed, it would be left with a net positive charge of 1 Coulomb

$$Q = 1\ C$$

If an electrically neutral body has $6.24x10^{18}$ electrons added, it would be left with a net negative charge of 1 Coulomb

$$Q = -1\ C$$

For our purposes, we are interested in the charge moving through a wire. If $6.24x10^{18}$ electrons pass through a wire, we say that the charge that passed through the wire is **1C**.

Voltage

Voltage use the electrical pressure that causes current to flow in a circuit. It is measured in VOLTS (V or E).whoWhen charges are detached from one body and transferred to another, a ***potential difference or voltage*** results between them. A familiar example is the voltage that develops when you walk across a carpet. Voltages in excess of 10,000 volts can become created in this way.

The Definition of Voltage

The voltage between two points is one volt if it requires one joule of energy to move one Coulomb of charge from 1point to the other.

$$V = \frac{W}{Q}$$

where:
W is energy in joules
Q is charge in Coulombs
V is the resulting voltage

The Concept of Voltage

The concept of voltages tied to the concept of potential energy. We said before, that a voltage develops when you walk across a carpet. This voltage continues to exist even after you stop moving. If you touch a metal object this potential energy is released.

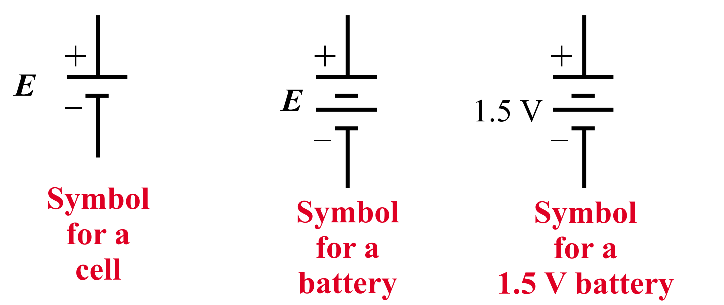
A more practical energy source is a battery. A standard flashlight battery has a voltage of approximately 1.5 V at its terminals. The voltage (or potential difference) exists ***between*** the two terminals.

A more practical way to understand voltage is to view it as the pressure or force that pushes the electrons around the circuit.

Symbols for DC Voltage sources

The battery is a source of electrical energy that moves charges around the circuit.

Because one of the battery terminals is always positive and the other is always negative, current is always in the same direction.



Note: The long bar denotes the positive terminal and the short bar the negative terminal. Thus it is not necessary to put + and- signs .on the diagram. This is often done for simplicity.

Fig 7

This is called DC or direct-current and the battery is called a DC source. Symbols for DC sources are shown to the right above.

Current

Look at figure 8 shown below. It shows a closed electrical circuit with the battery pushing electrons through the wire and through the lamp. This movement of charge is called an electric current. The more electrons per second that pass through the circuit, the greater the current. Current is the ***rate of flow (or rate of movement)*** of charge.

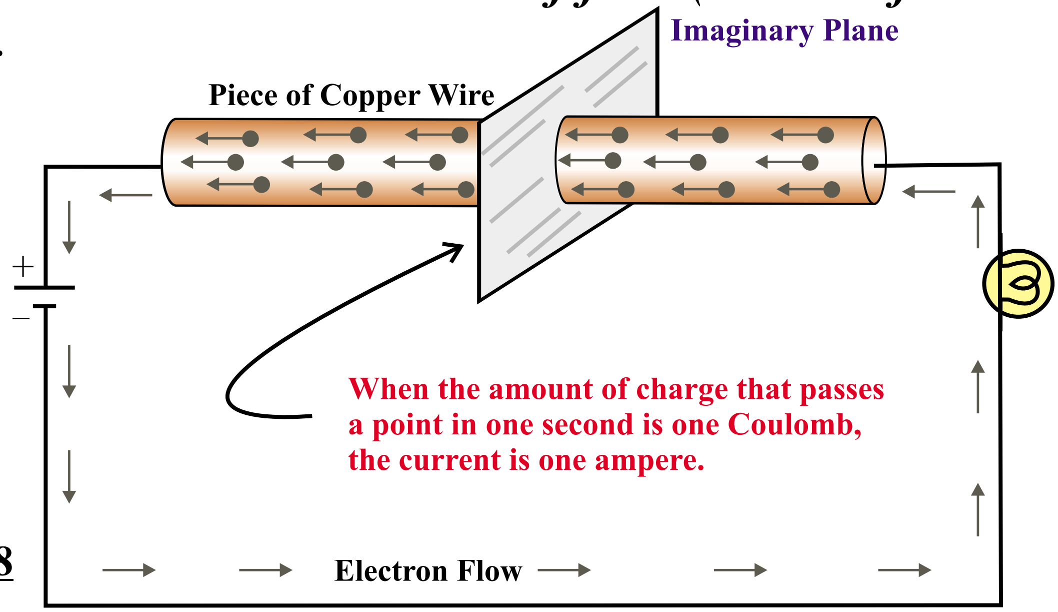


Fig 8

The Ampere

In Fig. 8 above, we measure the rate of electron (current) flow in amperes. The symbol for current is I.

One ampere is the current in a circuit when one Coulomb of charge passes a given point in one second.

$$I = \frac{Q}{t} \text{ [amperes, A]} \qquad Q = It \text{ [Coulomb, C]} \qquad t = \frac{Q}{I} \text{ [seconds, S]}$$

where: **Q is the change in Coulombs**
t is the time interval in seconds

Read Sections 2.5, 2.6 and 2.7 in the text